CONCEPTUAL CHANGES ARISING FROM THE USE OF A SEARCH INTERFACE DEVELOPED FOR AN ELEMENTARY SCIENCE CURRICULUM DATABASE

By

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by

William Michael Dwyer

This dissertation is dedicated
to the memory of Dr. Mary Budd Rowe,
the Master Gardener,
whose careful plantings continue to flourish
in her lush pedagogical gardens.

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Abstract of Dissertation Presented to the Graduate School
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By

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The purpose of this study was to look for evidence of change in preservice elementary teachers' notions of science teaching after practice using a search interface for a database of elementary science curriculum materials. The Science Helper K-8 CD-ROM uses search criteria that include science content and process theme to provide appropriate science lessons for elementary educators. Training that took place when Science Helper was first disseminated revealed the possibility that notions about teaching science change with use of the resource. This study looked for evidence of conceptual change compatible with notions in recent reform materials, such as the National Science Education Standards.

The study design consisted of a pretest-treatment-posttest model. The treatment included a brief training session in the use of Science Helper, followed by practical application, which consisted of finding appropriate lessons to form a science mini-unit. An analysis of covariance (ANCOVA), however, did not find significant differences between pretest and posttest scores for the treatment group.

Study participants also wrote brief narratives about their experiences using Science Helper. A pattern analysis of the narratives found that most of the preservice teachers had positive experiences, saying the resource was easy to use and contained many interesting science activities. A closer examination of the comments revealed a subset of participants who expressed an understanding of the importance of criteria searches and the relatedness of the lessons produced. An ANCOVA of the treatment group controlling for pretest did not find significant differences between pretest and posttest scores for the group who expressed such understanding.

Science Helper, with its affordances as a teacher resource, can be regarded as a "knowledge system" in a distributed environment. The interactions among people and material resources in a distributed environment results in a distributed intelligence that is dynamic and expressed in those interactions. The results of this study suggest caution in expecting too much from the affordances of a resource alone. However, further research of both the material and social interactions in distributed environments may lead to a

better understanding of how such interactions contribute to changes in higher order knowledge and transfer across situations.

CHAPTER I
INTRODUCTION

> [T]he Standards call for dramatic changes throughout school systems. They emphasize a new way of teaching and learning about science that reflects how science itself is done, emphasizing inquiry as a way of achieving knowledge and understanding about the world. They also invoke changes in what students are taught, in how their performance is assessed, in how teachers are educated and keep pace. (NRC, 1996, p. ix)

Reform efforts in science education require the training and retraining of teachers who, for the most part, have more than 12 years of educational experience that most often does not represent appropriate approaches to learning about science. The National Science Education Standards (NRC, 1996) provide a guide for reform efforts and teacher training in science teaching, professional development for teachers of science, and science content standards, but the question remains of how best to promote the necessary conceptual changes for teachers to adopt the Standards in their own practices. In particular, teachers of science should learn how to use inquiry approaches to learn about science (NRC, 1996). One possible tool for promoting such changes is the Science Helper CD-ROM (University of Florida, 1993), a teacher resource consisting of a large, searchable database containing many inquiry-based science lessons and activities, along with relevant mathematics activities.

The Science Helper CD allows teachers to use relevant criteria in their search of its database for appropriate science and mathematics activities for use in their curricula. In particular, teachers can find activities that use the processes of science, thus promoting an inquiry approach to learning about science (see Appendix A which shows an example of a Science Helper search window). In this study, preservice teachers used Science Helper to find activities for a topic of their choice. The purpose of the study was to see if minimal experience working with Science Helper would lead to changes in teachers' concepts of how to teach science, according to appropriate practice described in the Standards.

The research design used in this study was a pretest-treatment-posttest design. The participants in the treatment group worked with Science Helper over a two-week period. They were given a pretest at the beginning of the period and a posttest at the end. In addition, at the end of the session the participants reflected on their experiences by writing brief narratives. A control group of similar preservice teachers also was given a pretest, followed by a posttest, after a similar period but without having worked with Science Helper. They were not asked to write narratives.

The two dependent variables examined in the study were (a) posttest scores on standards-based multiple choice questions about teaching science (Appendix D) and (b) participant narrative comments reflecting on experiences using Science Helper, in particular, comments reflecting appropriate usage of the search criteria. The independent variables were the use of Science Helper to develop a mini-unit of science lessons and the form of the test.

Science Helper and Teaching Science as Inquiry

The first version of the Science Helper CD-ROM became available more than 10 years ago (1987) when the technology was still in its infancy. Since that time more than 1500 units have been distributed. Informal queries have indicated that science educators are familiar with the product and consider it to be a useful resource for science education; however, in most cases, teachers use the resource with little or no training. Whether they understand the importance of using search criteria, such as the science process themes, is not known. This study looked at whether limited experience in using the resource leads to appropriate notions about teaching science.

The rhetoric associated with the Standards implies the need for very fundamental changes in teachers' understanding of what it is to do science. In using Science Helper, teachers select criteria to find sets of activities within its database of nearly 1,000 lessons embedded in eight elementary science curriculum projects. While the need to assemble lessons that reflect state and national standards was part of the original design intent, the role that Science Helper has played in helping teachers attach meaning to the

Standards--and to make connections called for by the Standards--has not been studied.

Although Science Helper predated the publication of the National Science Education Standards (NRC, 1996) by a number of years (the Standards were not published in draft form until several years after Science Helper's publication), the search interface embedded in this resource anticipated those Standards. In particular, the content and process themes in the search criteria are reflected in the more recent Standards. Science Helper's content themes include energy, instruments, interaction/change in systems, patterns in nature, space/time relationships, a statistical view of nature, structure of matter, and systems. Science Helper process themes include applying/problem solving, classifying, communicating, controlling variables, experimenting, hypothesizing, inferring, interpreting data, measuring, modeling, observing/recording, operationally defining, predicting, and using math/equations.

These themes are reflected in the Standards, particularly under the two content standards categories, "unifying concepts and processes in science" and "science as inquiry." The first category includes systems, order, and organization; evidence, models, and explanation; change, constancy, and measurement; evolution and equilibrium; and form and function (NRC, 1996, p. 104). The second category, specifically the "abilities necessary to do scientific inquiry," includes systematic observation, making accurate measurements, identifying and controlling variables, formulating questions, designing and executing investigations, interpreting data, using evidence to generate explanations, proposing alternative explanations, and critiquing explanations and procedures (NRC, p. 145). Additional abilities include using appropriate tools and techniques to gather, analyze, and interpret data; developing descriptions, explanations, predictions, and models using evidence; and communicating scientific procedures and explanations.

Understanding the science process skills, which form the backbone of "science as inquiry" in the National Science Education Standards (NRC, 1996), has been considered an integral component of science education. The curriculum project, Science--A Process Approach (SAPA), which is contained in the Science Helper database of science lessons, popularized these skills (Padilla, 1990). Many studies have been done on the efficacy of teaching science process skills. Bredderman (1985) looked at 57 evaluations of SAPA, along with the Elementary Science Study (ESS), and the Science Curriculum Improvement Project (SCIS), projects that also are contained in the Science Helper database. He found an overall positive effect from teaching the science process skills.

Concerning the training of teachers in the use of science process skills, Barufaldi, Huntsberger, and Lazarowitz (1976) considered the influence of inquiry-based projects such as SAPA, ESS, and SCIS. They found that preservice elementary teachers' attitudes toward inquiry teaching strategies improved after taking a methods course that explored the content, methodology, and science processes behind such strategies. This finding was reinforced by Campbell and Okey (1977) who looked at research indicating preservice teachers performed poorly on process-skills tests, despite college-level science instruction. However, they found that instructing preservice teachers in process skills significantly altered their knowledge of such skills.

The original proposal for Science Helper included only grade level and keywords as search criteria, but subsequent meetings among the science educators who consulted on the project led to the incorporation of the information-dense search criteria that included the content and process themes, as well as grade level, keywords, and subject areas (R. Melczarek, personal communication, April 1, 1998). At first, project consultants were satisfied with keyword and grade level searches, but it was suggested that teachers might not know which of the many activities to use after such a limited search. Further discussion led to the inclusion of subject area as another search category, but the criteria were still too broad for producing a reasonable number of lessons in a search. The effort eventually led to the development and inclusion of the content and process themes in the search criteria categories.

During the trial period and early release of the Science Helper CD-ROM, the project staff introduced the resource to teachers and science educators. Participants in these early awareness and training sessions appeared to be changing their ideas and attitudes about teaching science (E. D. Britton, personal communication, April 27, 1998). No research had been done to test whether using Science Helper led to changes in teachers' concepts of how to teach science, thus the undertaking of this study. Having heard that such conceptual changes might occur with the use of Science Helper, this researcher found resonance in this possibility and descriptions of distributed knowledge and distributed cognition in distributed environments.

Science Helper as a Tool in a Distributed Environment

According to the research literature, to think that knowledge or intelligence is distributed offers advantages over thinking that knowledge is static. A distinction first should be made between "knowledge" and "intelligence" within this view. To say that knowledge is distributed can mean simply that people, books, computers, and other tools in the environment are sources of knowledge. However, such knowledge still can be static. A revised view defines knowledge as what occurs when agents interact in certain ways. In other words, knowledge is dynamic rather than static. This distinction can be improved by using the term "intelligence" to refer to such dynamic interactions and leaving "knowledge" to refer to static elements. Intelligent interactions within the distributed environment, therefore, provide opportunities to change or revise knowledge.

Pea (1993) also made a distinction between "intelligence" and "cognition" in distributed environments. Because only people "do" cognition, it is not distributed. Pea made another distinction between the social and material distribution of intelligence. Guided participation in parent-child interactions or collaborative efforts among people represent the social component. According to Pea, the use of elements in a distributed environment to achieve a purpose, including the use of affordances of designed artifacts, represents the material component. This study focused primarily on the material component and the affordances of a particular designed artifact, Science Helper; however, this focus should not imply that the material component holds greater importance than the social component.

The affordances of an artifact, in this case the Science Helper CD-ROM, determine the artifact's accessibility to the user. This accessibility depends upon how well the artifact has been designed, given the intended purposes for users. With the widespread availability of microprocessors, many artifacts offer varying levels of affordances in distributed knowledge systems. Pea (1993, p. 53) said that such artifacts are "tools" that "carry intelligence in them, in that they represent some individual's or some community's decision that the means thus offered should be reified, made stable, as a quasi-permanent form for use by others." These artifacts can be thought of as "smart tools," according to Lave (as cited in Pea, 1993).

Science Helper is one such smart tool, serving as a database for mathematics and science lessons and activities that are readily accessible through its search interface. Science Helper users can engage in a distributed intelligence activity with a goal of, for example, identifying lessons for incorporation into their elementary science curriculum. The knowledge that resides in this particular tool consists not only of the many activities themselves but of the search criteria assigned to lessons which allow users to quickly find appropriate activities. Users easily select search criteria (see Appendix A) "with little or no awareness of the struggle that went into defining them and to adapting their characteristics to the tasks for which they were created" (Pea, 1993, p. 53).

The theoretical implications of a distributed intelligence paradigm involve recognizing that knowledge resides in artifacts--and intelligence in interactions with them--not just in the people using them. In the case of Science Helper, the designed knowledge resides in the operations that allow the use of the CD's computer interface (the hardware and operating system software), the search system interface (software), and the original lessons (stored in digital form) with their corresponding criteria and abstracts.

Science Helper and Higher-Order Knowledge

The hypothesis that serves as the focus of this study postulates that this tool also may serve as a reorganizer of a user's mental functioning--not simply as an amplifier of cognition as computer tools are often construed (Pea, 1993). Specifically, to use the common distinction used in the literature, we can consider "effects *with* technology obtained during intellectual partnership with it, and effects *of* it in terms of a transferable cognitive residue that this partnership leaves behind in the form of better mastery of skills and strategies" (Pea, 1993; see also Salomon, 1992, 1993a, 1993b).

This discussion can be extended somewhat by distinguishing between a tool's *intended* effects and its *unintended* effects (Salomon, 1993b). A tool's intended effects are the designed features, which for Science Helper are the ability to find appropriate activities in its database at levels of conceptualization, ranging from primitive to advanced. What might be happening to teachers' understanding of standards and their pedagogical decisions with repeated use of the tool would serve as unintended effects of this tool.

It should be noted that the original intent of Science Helper was as an archive of exemplary science activities. This archive was to have a basic keyword interface for searching through the resources. As the search interface developed to include science content and process themes, the intent was seen as more than archival. Activities could be quickly found that represented specific science processes, for example, and then used to teach those processes. The final design of the search interface reflected its intended use as a resource for finding lessons with desired content and process skill characteristics, yet it was felt, even in these early days, that using Science Helper might lead to a better understanding of process skills and the importance of inquiry in science instruction.

This researcher looked for evidence of what, based on its design, might be considered the unintended effects of using Science Helper. This evidence, which would involve distributed intelligence as represented by the interactions of preservice teachers and Science Helper's search interface and database of activities, might be seen in changes in the teachers' ideas about teaching science. These unintended effects of using the resource might help teachers develop science curricula that meet the conditions of science standards (which are not themselves curricula)

How these unintended effects help teachers change their notions of teaching science may be represented in improvements in higher-order knowledge, which include "discipline-appropriate problem-solving strategies and patterns of justification, explanation, and inquiry characteristic of the discipline" (Perkins, 1993, p. 101). This new cognitive orientation more closely aligns with the goals of the Standards. The intent of this study was to identify an environment that not only improves access characteristics (identifying appropriate activities for a curriculum) but also cultivates higher-order knowledge of a pedagogical nature which is no longer distributed but has become internalized (Salomon, 1993b).

This framework can be further specified and refined using arguments presented by Perkins (1993), who described where the so-called "executive function" resides in a system of distributed intelligence. An example he gave that applies to the Science Helper interface involves the resource's menu system. In Science Helper, the user selects criteria and operations from pull down menus and windows on the computer screen (see Appendix A). The program anticipates the "user's likely priorities" and thus this tool "undertakes part of the executive function--constructing a representation of the option space" (Perkins, p. 97). An executive function consists of those decisions that have already been made, such as the criteria assigned to activities in the database and the rules used in finding activities using those criteria. In other words, in this designed environment, the user can make certain choices, but those choices are constrained by the knowledge embedded in this tool which derives from the knowledge of the experts who developed the tool (Spoehr, 1994).

Unlike knowledge that can reside in various components of a distributed intelligence system, higher-order knowledge resides solely in people (Perkins, 1993) and it should facilitate better and more independent thinking (Salomon, 1993a). According to Perkins, such stable, compact knowledge can reside in long-term memory, accessible in diverse settings, having the desired characteristics for transfer.

In addition to evidence of intelligence in the interactions among the components of a distributed system, the researcher looked for evidence of knowledge that, while obtained or enriched in a particular system of distributed intelligence, remains when that system changes with the removal or redistribution of people and artifacts, and which can be applied to problems arising in systems whose components no longer contain the intelligence from which that knowledge originated.

A question that arose in this study revolves around what constitutes evidence of transfer (e.g., Gage, 1992). For this purpose, the researcher used the interpretation of Greeno, Moore, and Smith (1993) in defining the characteristics of higher-order knowledge under the term, "reasoning." They applied this term "when an inference includes an operation that transforms a representation" (Greeno et al., p. 108). Such inferences "involve transformations of physical or mental propositional representations with processes that correspond to firing production rules" and include "inferences involving transformations of representations in physical or mental models involving simulations of events" (p. 108).

Greeno et al. (1993) further refined their concept of reasoning to include "conceptual reasoning" in which a representation used in reasoning contains those concepts that correspond to properties or relations in a domain. For example, what features of the lessons chosen in Science Helper made them qualify as a fit for one or more of the categories used for the search? In other words, how does the planning change with increasing use of the tool? The researcher's aspiration was to get a better understanding of teachers' efforts to work within the constraints of meeting the conditions of the Standards. "Knowing a set of concepts, including those of number and quantity, can be considered as analogous to knowing how to find and use things that are in an environment" (Greeno et al., p. 109). The researcher looked for evidence of such conceptual transfer.

Purpose

The purpose of this study was to determine whether the use of a tool, such as the Science Helper database with its associated search interface, could promote change in preservice teachers' concepts about how to teach science in ways that conform to reform efforts as expressed in the National Science Education Standards (NRC, 1996). The participants in the treatment group for this study were introduced to Science Helper and practiced using it to find appropriate science activities for a science mini-unit.

Research Questions

1. Does using Science Helper have an effect on preservice elementary teachers' concepts of how science should be learned?
2. What patterns manifest in preservice elementary teachers' comments on using Science Helper to find appropriate science activities for their future classrooms?
3. Do preservice elementary teachers whose comments show evidence of the importance of Science Helper search criteria also show greater improvements in their concepts of how science should be learned?

Significance of the Study

With the publication of the National Research Council's National Science Education Standards (1996), appropriate approaches and resources are needed for teacher education on how best to learn about science. Learning appropriate approaches, such as an inquiry-based approach to learning about science, requires changes in most teachers' notions about learning science. Available technological tools can be used to promote such changes and this study looks at the potential for using one such tool to promote appropriate approaches to learning about science.

According to Alberts (1996), the inquiry-based learning suggested by the Standards is a "major revolution." Alberts said that teachers must understand what inquiry is, despite never having experienced inquiry in their previous schooling. Experiencing inquiry in teacher development courses means enormous changes at colleges and universities, according to

Alberts. Besides teaching science and science pedagogy, he said that this effort requires making teachers aware, not only of the Standards, but of the outstanding curricula that are available for use in the schools. Science Helper contains much of what has been recognized as outstanding curricula which is referenced in an appropriate, inquiry-based manner through its search interface.

The researcher focused on the implications of that search interface in restructuring preservice teachers' understanding of appropriate methods for teaching science as inquiry, according to the National Science Education Standards (NRC, 1996).

Limitations

The study had limitations to generalization in that the sample was limited to preservice teachers. Therefore the results of the study apply to teachers with limited classroom teaching experiences.

Summary

This chapter introduced the purpose of the study, indicating a perceived need to promote teacher understanding of appropriate strategies to learning about science as described in the National Science Education Standards (NRC, 1996). This study looked at the possibility that the Science Helper CD-ROM (University of Florida, 1993) with its inquiry-based science activities and search interface might serve as a tool for improving teachers' notions about teaching science in line with the _Standards_. The study looked for such conceptual changes in preservice elementary teachers who used _Science Helper_ to find lessons for a science mini-unit. The theoretical framework for the study involved consideration of the effects on those who interact with such knowledge-based tools within a distributed environment and possible changes in their higher-order knowledge. A more thorough description of this theoretical framework is presented in Chapter II.

CHAPTER II
REVIEW OF THE LITERATURE

The purpose of this chapter is to provide a summary and analysis of the professional literature related to the questions addressed in this study of the effects on conceptual change for teachers using the Science Helper database and its search interface. The following quotation captures both the spirit as well as some of the terminology discussed in this chapter:

> All knowledge is, we believe, like language. Its constituent parts index the world and so are inextricably a product of the activity and situations in which they are produced. A concept, for example, will continually evolve with each new occasion of use, because new situations, negotiations, and activities inevitably recast it in a new, more densely textured form. So a concept, like the meaning of a word, is always under construction (Brown, Collins, & Duguid, 1989, p. 33).

This chapter contains three major sections: (a) reform expectations and conceptual change issues; (b) cognitive apprenticeships and distributed intelligence; and (c) expert knowledge tools and higher-order knowledge.

Reform Expectations and Conceptual Change Issues

The quotation and discussion at the beginning of Chapter I provided an introduction to expectations for reforming science education to help all students achieve scientific literacy. The National Science Education Standards are intended to "present a vision of a scientifically literate populace" (NRC, 1996, p. 2). Implementation of the Standards will require "major changes in much of this country's science education" (NRC, p. 2), calling for the development of inquiry skills in which students combine scientific knowledge with reasoning and thinking skills. Teachers are expected to design and implement appropriate ways of teaching and learning science, which will require that the practices, policies, and overall culture of most schools change.

Such expectations from supporters of the Standards require consideration of the potential for reform efforts as they apply to teacher education. The emphasis on science as inquiry requires particular attention in teacher education, considering that most students in teacher education programs have more than 12 years of educational experiences, including science instruction in which "even the science laboratories in most colleges fail to teach science as inquiry. . . . The vision of science and how it is learned as described in the Standards will be nearly impossible to convey to students in schools if the teachers themselves have never experienced it" (NRC, 1996, p. 56).

The question then remains of how much experience prospective teachers must have to change their concepts of how science is done and how science should be taught. This question is difficult to answer based on the limited amount of research that has been done on teacher education and reform of K-12 schools in general (Kyle, 1994); however, what evidence has accumulated paints a rather dismal picture for reform efforts. Kyle claimed that teacher education programs appear to support the status quo in education, while research has focused more on k-12 learners than on the adults in teacher education programs. Research that has been done indicates that concepts of learning preservice teachers bring to methods classes remain deeply ingrained (Guillaume, 1995; Lynch, 1997; Thorley & Stofflett, 1996). As a result, prospective teacher leave preparation programs with their beliefs largely intact (Feiman-Nemser & Remillard, 1996).

Stevens and Wenner (1996) found that elementary preservice teachers expressed much confidence in their abilities to teach science and mathematics and in their content knowledge. However, the teachers had much less confidence in their abilities to teach at a conceptual level or conduct process-oriented, hands-on experiences in the classroom. These results indicate confidence in their abilities to use traditional direct instructional methods while omitting instruction that requires conceptual understanding of the subjects.

During the many years students spend in school before entering teacher education programs, they have undergone what one researcher called the "apprenticeship of observation" (Lortie, 1975, as cited in Pajares, 1992, p.322). As a result, prospective teachers view teaching as "a process of transmitting knowledge and of dispensing information" (Pajares, p. 323; see also Stofflett, 1994; Stofflett &

Stoddart, 1994). Pajares said such students have taken and continue to take classes in college, including education classes, in which "the people and practices . . . differ little from classrooms and people they have known for years" and so they "become teachers unable, and subconsciously unwilling, to affect a system in need of reform" (Pajares, p. 323)

In conjunction with these general pedagogical concerns, Guillaume (1995) found that "learning to teach elementary science is a process of contextualizing science within one's more general conception of education" (p.98) In addition, Guillaume claimed that teachers' conceptions of science tend to differ substantially from those of scientists, and teachers' personal beliefs usually determine what and how science gets taught. Elementary teachers in particular tend to rely on textbooks as sources of expert knowledge and to teach didactically (Stofflett & Stoddart, 1994).

Research efforts in general have focused more on student outcomes than on reform goals (Kyle, 1994, as cited in Lynch, 1997). In science education, studies of conceptual change in children have been an important research area but the need for better teacher education in conceptual change is receiving more attention (Stofflett, 1994; Thorley & Stofflett, 1996). Lynch claimed that evidence of the resistance to change in prospective teachers, along with other evidence, indicates that reform efforts require much time, as well as effective approaches in professional development. According to Lynch, teachers whose beliefs are inconsistent with reform expectations need both time and appropriate activities to restructure their beliefs.

In research on conceptual change and human judgment, Feiman-Nemser (1996) indicated that change “is more likely to occur if alternatives are vivid, concrete, and detailed enough to provide a plausible alternative” (p. 81). Lynch (1997) claimed that “nothing short of a meaningful intellectual encounter with the reform materials is likely to influence teachers’ beliefs, empower teachers to enact science curricula consistent with reform goals or intelligently reject the goals, or create new communities of learners allied for meaningful change” (p. 6).

Cognitive Apprenticeships and Distributed Intelligence

Understanding how teachers learn to teach and, thus, providing experiences for developing appropriate concepts of teaching, requires a focus on teacher cognitions and “the conditions and opportunities that facilitate their learning” (Feiman-Nemser, 1996, p. 79). Teacher education programs should provide opportunities for prospective teachers to “consider why new practices and their associated values and beliefs are better than more conventional approaches” (Feiman-Nemser, p. 81). In addition, Feiman-Nemser claimed that prospective teachers should see examples of such practices under realistic conditions and experience them firsthand whenever possible.

According to Feiman-Nemser (1996), studies in learning indicate that "people build up knowledge by solving real problems using available clues, tools, and social supports" (p. 81). However, a study of prospective teachers who had science instruction that included extensive laboratory experiences found that the teachers' conceptual understandings were not significantly improved (Stofflett & Stoddart, 1994). In other studies of learning, according to Feiman-Nemser, researchers have recommended "cognitive apprenticeships" in education programs. Such apprenticeships include features of a traditional apprenticeship, such as authentic activity, social interaction, collaborative learning, and a "coach" whose knowledge and thinking are made available to the learner. The cognitive aspect emphasizes the development of cognitive skills over physical skills.

Choi and Hannafin (1995) claimed that "cognitive apprenticeships provide the opportunity for learners to internalize learning and develop self-monitoring and self-correcting skills" (p. 61). Such apprenticeships "emphasize relationships between the content knowledge and thought processes experts employ to perform complex tasks" (Choi & Hannafin, p.59). The basis for such cognitive apprenticeships lies in the finding that, to develop skills used by experts, learners need to engage in similar cognitive activities--in other words, engaging in "authentic tasks in authentic contexts" (Choi & Hannafin, p.56). These authentic tasks, which can be problem-solving activities, represent the ordinary practices of a culture (Brown et al., 1989) and emphasize problems students might encounter in everyday life (Anderson, Reder, & Simon, 1996). They are activities that "practitioners and experts engage in during real problem-solving situations, rather than the simulated processes typically demanded in formal schooling" (Choi & Hannafin, p. 56).

Problem-solving situations provide opportunities for authentic learning that is, in this sense, situated in that the cognitive skills used represent those used by experts. To be situated does not require that activities be done outside the classroom but that the activities experienced in the classroom are authentic in nature and purpose (e.g., Moore et al., 1994). Learning then becomes a "natural by-product of individuals engaged within contexts in which knowledge is embedded naturally" (Choi & Hannafin, 1995, p.53). This knowledge, according to Choi and Hannafin, does not consist of a static form that exists solely in the mind of an individual but is a "dynamic by-product of unique relationships between an individual and the environment" (p. 53). Another way of describing this view of knowledge is to say that knowledge or intelligence is "distributed" (Pea, 1993).

To think of knowledge or intelligence as being distributed offers advantages over concepts of static knowledge. First of all, a distinction needs to be made between knowledge and intelligence in this view. To say that knowledge is distributed can mean simply that people, books, computers, and other tools are sources of knowledge. Such knowledge can be thought of as having a static form. However, the new view holds that knowledge really is that which happens when people and other sources of knowledge interact in certain ways. In other words, knowledge is not static but dynamic and represented in actions.

It helps somewhat to use "intelligence" to describe this dynamic form of knowledge, leaving "knowledge" to refer to static forms the reside in people and material resources. Intelligent interactions provide opportunities for changes in knowledge within the distributed environment. Another way to put it, according to Pea (1993), is to say that "the resources that shape and enable activity are distributed in configuration across people, environments, and situations. In other words, intelligence is accomplished rather than possessed" (p. 50).

Pea (1993) also distinguished between intelligence and cognition, because only people "do" cognition and so it is not distributed[1]. In addition, Pea distinguished between the social and material distribution of intelligence. The social component is represented in such activities as guided participation in parent-child interactions or collaborative efforts among people. The material component, on the other hand, "originates in the situated invention of uses for aspects of the environment or the exploitation of the affordances of designed artifacts, either of which may contribute to supporting the achievement of an activity's purpose" (Pea, p. 50).

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[1] Salomon (1993a) discussed distributed cognition differently. In his view, cognitions are distributed among minds, bodies, activities, and culturally organized settings. In other words, a distinction should not be made between cognition by individuals, which are not distributed, and cognitions that are distributed. In this, he agreed with Pea, switching to the use of the term "intelligence" which is something that is accomplished rather than possessed.

It is this material component that receives greater attention in the current study and which will receive the most attention in the discussion of the literature that follows. However, this emphasis on the material component should not be construed as implying greater importance to this aspect, only that the nature of the study more closely focuses on this component.

Greeno, Moore, and Smith (1993) described "knowing" as "a property that is relative to situations, an ability to interact with things and other people in various ways" (p. 99). Later, Greeno (1997) made a similar knowledge/intelligence distinction as Pea but between knowledge and "knowing." His distinction, however, has similar grounds and is consistent with Pea's. "Knowledge," in Greeno's case, implies something that has substance or structure, whereas "knowing" is a more "process-invoking term" that "refers more appropriately to regular patterns in someone's participation in interactions with other people and with material and representational systems" (Greeno, 1997, p.

11). This distinction is sufficient for Greeno's view of "transfer of knowledge" to be discussed below.

Expert Knowledge Tools and Higher-Order Knowledge

Salomon (1993a) provided four clarifications on the definition of a tool as a device:

1. It need not be a real object but can be a symbol system or a computer program;
2. It consists of all the natural and cultural implications of its intended use (see also Choi & Hannafin, 1995), along with the knowledge and skills required for its use;
3. It serves functions beyond the nature of its composition; and
4. It functions beyond the autonomous nature of most machines.

Computer-based tools, for example, can be model-builders, data sets *affording* manipulation, conceptual map-makers, simulations, and various open-ended instruments allowing student operation and manipulation. Citing Pea (1985), Salomon (1993a) said that such devices become cognitive tools by serving "to aid students in their own constructive thinking, allowing them to transcend their cognitive limitations and engage in cognitive operations they would not have been capable of otherwise" (p. 180).

Greeno (1994) described J. J. Gibson's concept of "affordances" as the idea that, "in any interaction involving an agent with some other system, conditions that enable that interaction include some properties of the agent along with some properties of the other system. . . . Affordance refers to whatever it is about the environment that contributes to the kind of interaction that occurs" (p. 338). And within this concept, the term "abilities" refers to "the characteristics of agents that enable them to engage in activities" (Greeno et al., 1993, p. 102). Bringing these terms together in his broadened description of the affordance concept, Greeno (1994) described the "inherently relational" nature of the two terms, saying that "an affordance relates attributes of something in an environment to an interactive activity by an agent who has some ability, and an ability relates attributes of an agent to an interactive activity with something in the environment that has some affordance" (p. 338).

In a related discussion of how tools serve as artifacts of distributed intelligence, Pea (1993) claimed that an affordance "refers to the *perceived* and *actual* properties [italics added] of a thing, primarily those functional properties that determine just how the thing could possibly be used" (p. 51).

In the case of Science Helper, the artifact examined in this study, its "perceived" properties are those associated with its use as a resource for finding appropriate science activities in its database through use of its search interface. Science Helper's "actual" properties include its "intended" use, along with the addition--as far as the purport of this study is concerned--its potential effects as a change agent. In a similar light, Pea (1985) distinguished between “pedagogic” systems and “pragmatic” systems. Pragmatic systems provide tools that allow the user to accomplish something he or she would not be able to accomplish without those tools. The original intended use of Science Helper was as a pragmatic tool for providing appropriate science activities.

According to Pea (1985), pragmatic systems “may have the peripheral consequence of pedagogic effects, that is, they may contribute to understanding but not necessarily” (p. 84). The “actual” properties of such a tool thus place it in a system having both pragmatic and pedagogic capabilities. Making a similar distinction, Salomon (1993b) described such tools as either “performance oriented” or “pedagogical” tools. Pedagogical tools provide a much greater capability for upgrading intellectual performance or for acquiring and cultivating skills that can be generalized and used in the absence of that tool.

Salomon (1992, 1993a, 1993b) also considered the effects *with* versus the effects *of* computers in computer-based learning environments. He said effects *with* computers involve “changes in performance that become possible when one is equipped with a tool with which an *intellectual partnership* is created” (p. 251). Computer tools, unlike other tools, can offer users such an intellectual partnership wherein the cognitive burden of carrying out an intellectual task becomes shared between the user and the computer tool. It is in this way that cognitions become distributed (see previous footnote) through the pooling of both partners' knowledge. The embedding of knowledge in a computer tool, which is manifested as intelligence in interactions with human agents, can be seen in the use of computer programs called "expert systems" (e.g., Romiszowski, 1987).

Tools represent one category of expert systems (others include "tutors" or "tutees") that help users solve relevant problems in their fields (Romiszowski, 1987). Expert systems can "emulate human expertise in small, tightly defined and highly structured domains of complex problem-solving" (Romiszowski, p. 22). Pea (1985) claimed that computer programs as expert systems:

> . . . embody the knowledge of experts in making judgments in a field. Such systems emulate the reasoning and problem-solving abilities of human experts, and they are widely used as advisory aids in human decision making. They vary greatly in their representations of knowledge, its accessibility, its ease of modification, and in the degree to which it attempts to teach its user. (pp. 75-6)

Gisolfi, Balzano, and Dattolo (1993) defined an expert system as "an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise to bring about their solution" (p. 26). They added that the necessary knowledge for such high performance can be considered a model of the expertise of the best practitioners in a field. They also described such systems as "knowledge-based systems," which can be consulted as one would consult an expert for solving problems or making decisions, and which seems more appropriate to this discussion. According to

Romiszowski (1987), a skilled teacher employing an appropriate expert system, used initially by students to solve relevant problems, "may become a medium for the discovery learning by the student of the original experts' cognitive structures that are built into the system's knowledge base" (p. 27).

Although computer-based expert systems can be quite complex in their design and function, Science Helper, the artifact or tool used for this study, may qualify at the lower end of the range of expert system capabilities. However, a more simplified concept, that of an "expert model," probably suffices to describe the expert knowledge embedded in Science Helper. Orey and Nelson (1993), described an expert model as "typically a database of correct knowledge states for a given domain" (p. 60). Thus, Science Helper with its large database of science activities and its corresponding search interface may be more adequately described in this manner.

Ultimately, according to Orey and Nelson (1993), the goal of instruction "should be to replicate the knowledge structures and processes of the experts in the minds of the learner" (p. 62). Extending the concept of distributed intelligence, emphasis shifts from concerns about *where* knowledge resides--whether in a person or surround--to "what kind of knowledge is represented, how readily it is retrieved, and related matters" (Perkins, 1993, p. 90). In addition, concern about *how much* knowledge resides in a learner shifts to a more appropriate concern about how interactions in a distributed environment enhance higher-order thinking abilities.

Pea (1993) insisted that the distributed intelligence should focus entirely upon the actions taking place in such environments, rather than be concerned with what a person may, in a sense, “take away” from such interactions. Salomon (1992, 1993a) on the other hand focused on these “cognitive residues,” which also was the aim of this study. Regardless of the importance of interactions in a system of distributed intelligence, educators are concerned with what individuals can take from such interactions and apply to other situations. In other words, what can be “learned” and thus brought to bear to solve related problems or to apply to situations where a similar yet different system is available. In the case of educating future teachers, providing them with practice in the distributed environment of a methods class should leave “residues” that then can be applied in the different but related distributed environments of their future schools and classrooms.

Ideally, such cognitive residues take the form of improved higher-order thinking skills. Perkins (1993) described research showing that such higher-order thinking abilities include “discipline-appropriate problem-solving strategies and patterns of justification, explanation, and inquiry characteristic of the discipline” (p. 101). The main argument by Perkins and others (e.g., Salomon 1992, 1993b) is that, while intelligence may be distributed and depend upon the interactions among individuals and tools in the environment, a type of knowledge transfer takes place in which an individual improves upon his or her higher-order thinking skills. Salomon (1992, p. 252) describes a "partnership with a computer" that leaves a cognitive residue in the form of internalized guidance, which can "stimulate the development of yet underdeveloped skills, resulting in a higher level of skill mastery."

Further discussion of this issue includes how higher-order skills are represented and how such representations undergo change through interactions in distributed environments (e.g., Brown et al., 1989)[2]. In their conceptual change research, Thorley and Stofflett (1996) described the "intelligibility of an idea" as the "learner's ability to represent the idea, externally in discourse, or internally in thinking, imagining, and so on" (p. 320). Greeno's (1997) consideration of this topic, however, helps bring the discussion of representation into a perspective appropriate to the concept of distributed intelligence systems. In his view, the concept of knowledge as a substance or structure resident in the "knower" should be replaced with consideration of the "regular patterns" that occur in interactions among people, materials, and representational systems. In this new view, the "generality of knowing" replaces the previous view of knowledge as "something" that is transferred from a knowledgeable person or tool to the knower. (Greeno, p. 11).

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[2] It should be noted, however, that, in Salomon's (1993a) view, the traditional use of the term "representation" in individual cognition gets downplayed in a distributed view wherein situated actions and cognitions are more relevant.

As a final contribution to the discussion of interactions in systems of distributed intelligence in this study, Gorayska and Mey (1996) presented a model of such interactions in their illustration of what they called "the modern feedback loop" (p. 13). The main elements in their feedback loop are the natural cognitive environment, tools, and a set consisting of the fabricated cognitive environment, the fabricated physical environment, and the natural physical environment. For brevity, the natural cognitive environment might be described as the pool of human mental capacity. This environment generates tools which themselves, in turn, can be used to manipulate the other set of environments, perhaps resulting in the evolution of the natural cognitive environment. However, the authors also discussed how such tools might be used to manipulate or amplify the natural cognitive environment, which applies to this study, along with the potential for atrophy of the cognitive environment through becoming overly dependent on such tools, a topic that is the antithesis of the results desired by considerations in this study.

Summary

A more detailed background on the theoretical framework, which was introduced in Chapter I, was provided in this chapter. Reviews of the literature on reform issues and conceptual change theories and research were presented. An explanation of cognitive apprenticeships and distributed intelligence concepts and research also were reviewed, along with discussion of the effects of expert knowledge tools and potential changes in higher-order knowledge. The following chapter focuses on the methodology used in this study, including a description of the participants and the setting. The procedure used to collect data is described, followed by a description of the quantitative and qualitative approaches used to analyze the data.

CHAPTER III
METHODOLOGY

The purpose of this chapter is to describe the design and methodology used to investigate the effects of using Science Helper, a tool consisting of a large database of science activities accessible through a search interface, on preservice teachers' concepts of learning science. Both quantitative and qualitative approaches were used to evaluate teachers concepts about teaching science and attitudes about using the tool.

The investigation used an analysis of covariance design (ANCOVA) for measuring change in concepts about teaching science. Reflective narratives about participant experiences in using the tool provided insight into attitudes about the use of such a technology-based resource for teachers of science.

Research Design

The design used in this study was a pretest-treatment-posttest design with control. The treatment group consisted of two sections of an elementary science methods course and the control group consisted of a third section of the course. Sections were randomly assigned to treatment and control groups. Two forms of a pretest instrument were administered at the beginning of the study period to both the treatment group and the control group, and the same forms were administered at the end of the treatment to the treatment group and after the same length of time to the control group. (See the Instrument section for a description of the forms.) The treatment group consisted of 54 participants who completed both a pretest and a posttest. The control group consisted of 27 participants who completed both tests.

The treatment consisted of participants using the Science Helper database with its associated search interface to find appropriate science activities for a mini-unit of science lessons. The participants also matched appropriate content standards from the Sunshine State Standards for Science (Florida Curriculum Framework for Science, 1996) to lessons resulting from their searches. Upon completion of a mini-unit database, the participants were asked to write brief narratives, reflecting on their experiences using Science Helper and the content standards.

Variables

Dependent Variables

This study had two dependent variables: posttest results and participant narratives.

Posttest. This variable was defined as the number of correct answers on a multiple-choice instrument designed to measure conceptions of how science should be taught. Two complementary forms of the instrument were administered. The nature of the two forms is discussed in the Instrument section.

Participant narrative comments. At the end of the treatment period, participants were asked to write a brief narrative, reflecting on their experiences during the treatment period. Their responses were guided, but not explicitly determined, by a set of statements requesting information on their experiences.

Independent Variables

This study had two independent variables: the treatment and the form of the test. The treatment took place over a two-week period during regularly scheduled class times for participants elementary science methods class. The treatment activity took place in a university computer lab. After a brief introduction on how to use the Science Helper search interface to find appropriate science lessons in its database, the participants used lab computers to practice using the interface and then to find lessons on a topic of their choice. The participants transferred information on found lessons to a database (template provided) and then identified appropriate content standards.

Hypotheses

The following research hypotheses were tested for treatment effects:

$\underline{H_0 1}$: There are no significant effects of treatment on preservice elementary teachers' concepts of how to teach science.

$\underline{H_0 2}$: For the teachers in the treatment condition, there are no significant effects of treatment on concepts of how to teach science between those whose comments showed evidence of understanding the Science Helper search criteria and those who did not.

Instrument

The instrument was researcher developed. Multiple choice items were developed related to appropriate teaching based on recent standards. Most of the items were based on the National Science Education Standards (NRC, 1996) for Science Teaching and Professional Development for Teachers of Science (NRC, 1996). Of the four choices for each item, one choice represents the accepted concept for teaching science. Instrument validity was established by two other science educators.

Before administration, the instrument items were divided randomly between two forms of 16 items each. Participants in both the treatment group and the control group were randomly assigned to a form.

Participants

Participants in this study were preservice elementary teachers from three sections of an elementary science methods course. The participants were undergraduate students at the junior or senior level. In the treatment group, 54 participants completed both the pretest and the posttest. In the control group, 27 participants completed both tests. Two sections of the methods course were randomly selected for treatment the treatment group and another section for the control group.

Setting

The setting for the study was a two-week period at the very end of a semester course in elementary science methods for two sections of preservice teachers at the University of Florida. The participants were not engaged in any other activities for the class at this point in the semester and focused entirely on the components of the study during regular class periods. Classes were held in a university computer lab located in the education building.

Science Helper was originally developed as a CD-ROM but for this study the Science Helper database of science activities and its associated search interface were placed on a server in the educational technology department. Participants accessed the server from their computers in the computer lab.

Procedure

The pretest was administered at the beginning of the first session. Participants were not told anything at that time other than that they should try to answer the multiple choice items to the best of their ability. No discussion of test items took place during the study session and neither the purpose of the test nor its relation to activities during the study period were disclosed. After administration of the pretest, the participants were introduced to Science Helper by the researcher who provided all instructions during the study period.

The participants met in a computer lab for a one-hour and a two-hour session each week of the two week study. All of the study materials were available through the computers in the lab so that participants could continue to work on study tasks outside of the scheduled class sessions.

The participants were allowed to work together in pairs or individually while working with Science Helper. The participants were allowed time to practice using the search interface (see Appendix A), selecting various search criteria at random to locate activities. They were then introduced to the science strands in Science for All Students (Florida Department of Education) and the related Sunshine State Standards for Science (Florida Curriculum Framework for Science, 1996). These documents were accessed from their online sites (see List of References for World Wide Web addresses).

Using examples from the areas of focus and the state content standards in Science for All Students (Florida Department of Education, n. d.), the participants were shown how to use the wording of those items to select search criteria (Appendix B), especially for selecting content themes and processes of science criteria in the Science Helper search interface. The participants then practiced using Science Helper by doing a focused search to locate three or four appropriate activities.

After finishing their initial search, the participants were asked to email the lesson titles they found to the researcher at which time they would receive an email message in reply that would describe the main assignment for the study period (see Appendix C). This assignment consisted of using Science Helper to identify three or four activities that could be incorporated into a science mini-unit based on a topic of their own choosing.

The participants were told the following:

1. The content standards could be used as a possible sources for finding a topic if they did not already have one in mind.
2. They should choose search criteria that reflect the knowledge and skills required for their students to understand the science topic chosen.
3. The appropriateness of the search criteria would be evidenced by how well the criteria matched the language of the content standards.
4. The most important criteria for a search were the content themes and process themes; however, they were not given any further instruction in the significance of the different criteria.
5. They should find additional content standards that matched the activities they found in their search.

The participants were asked to include the following information in their database templates (see Figure 3-1 for an example of a participant's database entry):

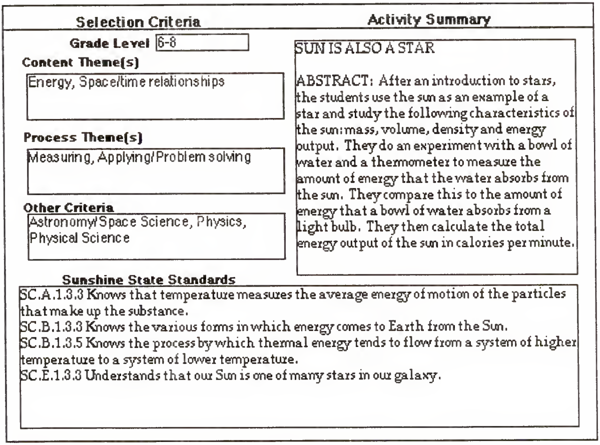
1. summaries of activities, including lesson titles, materials, and procedures;
2. selection criteria (grade level, content themes, process themes, and others) used for the search; and
3. content standards addressed by each of the activities.

Each activity they found in their search represented a new record in their database. Instructions on how to fill out records in the database were provided during the class time. After they had completed their mini-unit database, the participants were instructed to write a brief narrative of their experiences in doing the assignment. The narrative was to include the following:

1. a brief description of how they chose the topic for their mini-unit;
2. a discussion of why they chose to use each of the search criteria;
3. a brief discussion of how they might go about using the activities together as a unit;
4. their comments about the advantages of identifying appropriate activities in this way; and
5. any other comments or concerns they had about doing the assignment.

The participants were asked to email any questions or concerns they had about the assignment. Otherwise, they were allowed to complete and submit the assignment on their own.

At the end of the study session, the posttest was administered. The posttest items were identical to those in the pretest but in a slightly different order. As with the pretest, no instructions were given other than that they should answer all items to the best of their abilities. No discussion of the items or of the relationship of the test to the preceding activities took place before, during, or after the posttest was administered.



Selection Criteria

Grade Level 6-8

Content Theme(s)

Energy, Space/time relationships

Process Theme(s)

Measuring, Applying/Problem solving

Other Criteria

Astronomy/Space Science, Physics, Physical Science

Activity Summary

SUN IS ALSO A STAR

ABSTRACT: After an introduction to stars, the students use the sun as an example of a star and study the following characteristics of the sun: mass, volume, density and energy output. They do an experiment with a bowl of water and a thermometer to measure the amount of energy that the water absorbs from the sun. They compare this to the amount of energy that a bowl of water absorbs from a light bulb. They then calculate the total energy output of the sun in calories per minute.

Sunshine State Standards

SC.A.1.3.3 Knows that temperature measures the average energy of motion of the particles that make up the substance.
SC.B.1.3.3 Knows the various forms in which energy comes to Earth from the Sun.
SC.B.1.3.5 Knows the process by which thermal energy tends to flow from a system of higher temperature to a system of lower temperature.
SC.E.1.3.3 Understands that our Sun is one of many stars in our galaxy.

Figure 3-1. Sample Database Entry

Data Analysis

Descriptive statistics were obtained, including the mean and standard deviation of both the control and treatment groups, for the pretest and posttest scores. The data were analyzed using an analysis of covariance (ANCOVA) procedure

(Borg & Gall, 1989). All inferential statistics were analyzed at a significance level of 0.05.

Narrative data was coded and analyzed for pattern frequencies. The main types of patterns identified included comments about science and science teaching, references to search criteria, positive and negative comments about Science Helper and about the study, comments indicating appropriate and undesirable usage of Science Helper, and comments about how activities found in Science Helper can be used to help students learn about science.

In addition to looking at pattern frequencies, data for participants displaying an understanding of appropriate usage of Science Helper were analyzed using the ANCOVA procedure. This analysis, essentially a t-test controlling for pretest inside the treatment group, looked for significant improvements in posttest scores for those who expressed understanding in their comments compared to those who did not. In other words, whether participants who displayed an appropriate understanding of Science Helper also showed greater improvement in their notions of appropriate science teaching.

Summary

The methodology used in this study was presented in this chapter. The research design, variables, hypotheses, instrument, participants, setting, procedure, and data analysis were described. An ANCOVA design was used to look for change in preservice teacher concepts about teaching science. Reflective narratives about participants' experiences were collected to provide insight into attitudes about the use of a technology-based resource such as Science Helper. Patterns were identified within the narrative comments. The next chapter describes the results of the data analysis.

CHAPTER IV
RESULTS

The purpose of this chapter is to present results of investigating the effects on cognitive change of preservice teachers who worked with the Science Helper database and its search interface (main treatment effect). In addition, comments from the participants on their experiences working with Science Helper are examined, categorized, and summarized. The relationship between apparent understanding of the appropriate usage of Science Helper and test scores also is described.

Analysis of Main Treatment Effect

Descriptive Statistics

Table 4-1 shows the mean scores and standard deviations for the control group. Table 4-2 shows the mean scores and standard deviations for the treatment group.

Table 4-1

Control Group Mean Scores and Standard Deviations

Variable	N	Mean	SD
Pretest	27	10.407	3.885
Posttest	27	11.741	2.246

Table 4-2

Treatment Group Mean Scores and Standard Deviations

Variable	N	Mean	SD
Pretest	54	11.704	2.485
Posttest	54	12.130	2.458

Hypothesis Testing

Treatment Effects on Concepts of Teaching Science.

H_o1: There are no significant effects of treatment on preservice elementary teachers' concepts of how to teach science.

The hypothesis, H_o1, could not be rejected. The analysis indicates no significant effect from the treatment ($F = 0.01$; $p > 0.05$). Treatment and control group data appear to be completely intertwined in the graph of pretest versus posttest scores (Figure 4-1). Also, the interaction of pretest and treatment was significant ($F = 6.67$; $df = 1, 77$; $p < 0.05$), indicating slopes are not equal and violating an ANCOVA assumption.

As indicated in the methodology chapter, two complementary forms of the instrument were administered. Initial analysis showed no significant interactions resulting from the different forms, thus the nonsignificant effects of form and form crossed with treatment were dropped from the model. See Tables 4-3 and 4-4.

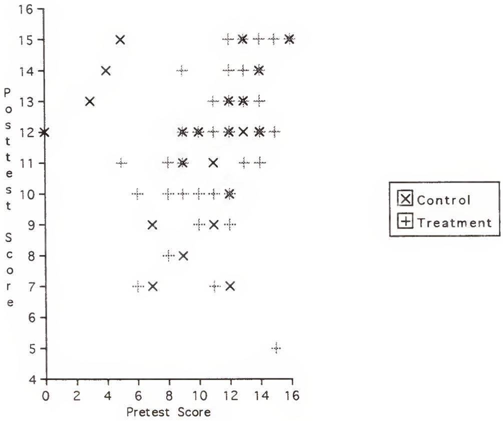


Figure 4-1. Pretest vs. Posttest Scores

Note: 34 data points are hidden in Figure 4-1.

Table 4-3

Analysis of Covariance: Treatment Effect with Form

Source	df	SS	F	p
Pretest	1	47.121	9.27*	0.003
Treatment	1	0.050	0.01	0.922
Form	1	8.494	1.67	0.200
Form*Treatment	1	2.268	0.45	0.506

*p < .05

Table 4-4

Analysis of Covariance: Treatment Effect

Source	df	SS	F	p
Pretest	1	49.065	9.52*	0.003
Treatment	1	0.044	0.01	0.927

*p < .05

Analysis of Narrative Data

Pattern Identification and Descriptive Summary

The narratives collected at the end of the study consisted of participants' reflections on using Science Helper. Participants were asked to provide the following:

1. a brief description of how they chose the topic for their mini-unit;
2. a discussion of why they chose to use each of the search criteria;
3. a brief discussion of how they might go about using the activities together as a unit;
4. their comments about the advantages of identifying appropriate activities in this way; and
5. any other comments or concerns they had about doing the assignment.

The 53 narratives[1] were analyzed for general patterns in the comments. These patterns and their frequencies have been summarized in Table 4-5. Only one count per narrative was made for each category. Most of the narratives (94 percent) contained comments of a general nature about science and science teaching. Most of the narratives (81 percent) also referred to the process and content themes in Science Helper's search criteria. Most of the narratives (81 percent) contained one or more positive comments about Science Helper or the study experience. A lesser number of narratives (34 percent) contained negative comments about Science Helper or the study experience. Some narratives contained both negative and positive comments, thus a combined result of greater than 100 percent for positive and negative comments.

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[1] The difference between numbers of narratives and numbers of participants in the analysis of the instrument resulted from a few participants who completed narratives but did not do a posttest and vice versa.

Table 4-5

General Pattern Categories and Frequencies

Categories	Number	Percent
General notions about science and science teaching	50	94
References to search criteria content and process themes	43	81
Positive comments about Science Helper or study	43	81
Negative comments about Science Helper or study	18	34
Comments indicating appropriate usage of Science Helper	21	40
Comments indicating undesirable usage of resource	10	19
Comments on how activities help students learn	37	70

About 40 percent of the narratives contained comments indicating appropriate usage of Science Helper while 19 percent contained comments indicating inappropriate or undesirable usage of the resource. About 70 percent of the narratives contained comments about how the activities found through Science Helper searches could be used to help students learn about science.

Further analysis of the narratives revealed important subsets of the general pattern categories. The negative and positive comments were subdivided into whether the comments referred to Science Helper or to the study experience. Frequencies of these subsets have been summarized in Table 4-6. Only one count per narrative was included in each category. Totals are greater than those in Table 4-5 because some narratives contained comments about both Science Helper and the study experience. Positive comments about activities in the Science Helper database were not included in these counts.

Table 4-6

Number and Percent of Participants Offering Positive and Negative Comments

Topic	Positive	Negative
Science Helper	37 (70%)	12 (23%)
Study	19 (36%)	11 (21%)

The nature of the positive and negative comments regarding Science Helper and the study experience have been paraphrased in the lists in Tables 4-7 and 4-8.

Table 4-7

Nature of Comments Regarding Science Helper

Positive	Negative
Contains great or valuable activities or ideas	Resource is time-consuming to use
Saves time and effort for the teacher	Activities are limited or difficult to access
Search criteria are good or useful	Activities are hard to read or understand
Activities found through a search are well-related	Activities are not practical
Searches provide the most appropriate activities	Resource is not widely available
Great for finding activities or ideas for teaching	Searches too often end up with no activities
Students will benefit from or enjoy activities	Teachers do not choose activities by process themes

Table 4-8

Nature of Comments Regarding the Study

Positive	Negative
Great learning experience	Assignment was not useful or was confusing or frustrating
Thanks for the opportunity	Had problems using computer
Provided greater confidence for teaching science	Communicating by email was not convenient

Twenty-two study participants made positive comments that could apply to either Science Helper or the study experience or to both. These comments consisted of simple expressions, such as that it was helpful, fun, interesting, advantageous, beneficial, or that it was a good resource, but with no further explanations.

A subset of positive comments were identified as "advantages to using Science Helper" and consist of two types. The first type of advantage involves the ease of using

Science Helper or its speed in finding activities or ideas for teaching science, as well as its large choice of activities and ideas. Twenty-five narratives (47 percent) contained this type of comment.

The second type of advantage involves finding the best or most appropriate activities through use of the search criteria, including the importance of the criteria for doing so. Fifteen narratives (28 percent) contained this type of comment. This second type also includes the advantage that activities found through searches are related or form a unit, and it is a broader category than the one identified in Table 4-7, "searches provide the most appropriate activities."

Comments indicating appropriate usage and comments indicating inappropriate, or undesirable, usage of Science Helper have been subdivided and summarized in Tables 4-9 and 4-10. Note that the totals for these categories exceed the numbers listed in Table 4-5 because of narratives that contained comments pertaining to more than one subset of the main categories. Note also that the category, "comments indicating appropriate usage of Science Helper," is a broader category than the one summarized in Table 4-9 which pertains to comments specifically acknowledging that activities found through a search are related because they have the same criteria.

Table 4-9

Comments Indicating Appropriate Usage of Science Helper

Comment Type	Number	Percent
Used process and comment themes as search criteria but content standards not mentioned	14	26
Used themes as search criteria after considering content standards	4	8
Acknowledged activities found from search are related by search criteria	4	8
Indicated best activities found using search criteria but not keywords	2	4

Table 4-10

Comments Indicating Undesirable Usage of Science Helper

Comment Type	Number	Percent
Randomly selected criteria	6	11
Keywords used as main criteria for search	3	6
Preferred doing topical search	1	2
Picked criteria simply to reduce number of activities available	1	2

Treatment Effect on Appropriate Usage

A closer evaluation was made of the 21 narratives that contained comments indicating appropriate usage of Science Helper (see Table 4-5). This evaluation considered comments evidencing a more cohesive understanding of the importance of science process and content themes in criteria searches (see Appendix E for examples of coding). Such evidence consisted of narratives describing the advantages of using Science Helper to find the best or most appropriate activities through the search criteria, along with comments that the activities found are related or form a unit because of the criteria used in the search (see Table 4-9). Seventeen of the 21 narratives satisfied this evaluation (interreader reliability of 0.94). Of the study participants involved, 16 completed both pretest and posttest and were used in the following analysis.

It should be noted that the identified comments were not directly elicited; in other words, the absence of such comments in narratives does not imply that subjects did not possess such an understanding at the end of the study period.

Descriptive Statistics

This analysis compares participants showing an understanding of the usage of Science Helper, as described above, with the rest of the treatment group (Others). Descriptive statistics for the two groups (Understanding and Others) follow in Tables 4-11 and 4-12.

Hypothesis Testing

Treatment Effects on Understanding Appropriate Use of Science Helper.

H_O2: For the teachers in the treatment condition, there are no significant effects of treatment on concepts of how to teach science between those whose comments showed evidence of understanding the Science Helper search criteria and those who did not.

Table 4-11

Mean Scores and Standard Deviations for Understanding

Variable	N	Mean	SD
Pretest	16	11.938	3.021
Posttest	16	13.063	2.112

Table 4-12

Mean Scores and Standard Deviations for Others

Variable	N	Mean	SD
Pretest	38	11.605	2.261
Posttest	38	11.737	2.511

The hypothesis, H_o2, could not be rejected. The analysis indicates no significant treatment effect for participants whose comments showed evidence of appropriate understanding of the search criteria ($F = 3.45$; $p < 0.07$), as can be seen in Table 4-13. The difference between the adjusted mean scores for the two groups is 1.17 points. Figure 4-2 shows a graph of pretest versus posttest for treatment subjects who displayed an understanding of the importance of Science Helper search criteria, as compared to the rest of the group. The assumption of equal slopes was met ($F = 0.20$; $df = 1, 50$; $p > 0.05$). In the graph (Figure 4-2), the distributions of data points for both groups appear to be linear (assumption of linearity) and the point spreads appear to be about the same (assumption of equal variances).

Table 4-13

Analysis of Covariance: Understanding

Source	df	SS	F	p
Pretest	1	74.757	16.9*	0.0001
Understanding	1	15.264	3.45	0.069

*p < .05

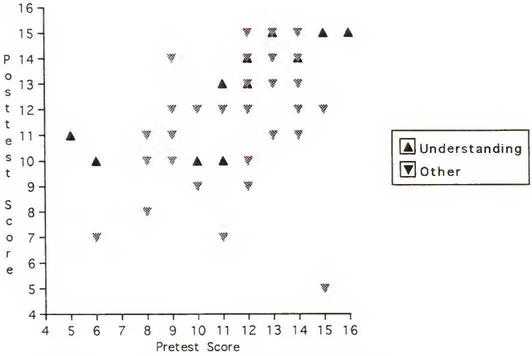

Figure 4-2. Pretest vs. Posttest Scores--Understanding

Note: 18 data points hidden in graph.

Summary

The results of the analysis of data collected in this study were described in this chapter. An ANCOVA showed no significant effect from the treatment as measured by test scores. Reflective narratives were analyzed for general patterns in the comments and pattern frequencies were summarized. Subsets of these general patterns also were described and their frequencies were reported. Comments indicating appropriate usage of Science Helper; however, an ANCOVA indicated no significant treatment effect for those participants whose comments showed evidence of appropriate understanding of the search criteria when compared to others in the treatment group. The next chapter discusses these results and implications for future research.

CHAPTER V
CONCLUSIONS

> If we want a world in which people do maintain some sense that they can influence the direction and quality of their destinies, then we need to provide a decent education in the sciences broadly conceived. Scientific and social inquiry must go hand-in-hand in the world we now face. . . . Each decision will have far-reaching consequences because everything seems to be related to everything else. (Mary Budd Rowe, 1978, p. vii)

The purpose of this study was to investigate evidence of cognitive change in preservice science teachers who used the Science Helper database and its search interface. The results indicated no significant improvement in preservice teachers' notions about appropriate science teaching after engaging in limited interactions with Science Helper. Participant narratives reflecting their experiences in working with Science Helper also were analyzed to look for patterns of comprehension of the resource's search interface. Patterns indicating the perceived value of the resource for teaching science were identified. Participants whose comments indicated understanding of the importance of process and content themes for finding appropriate activities in Science Helper's database also were analyzed; however, those participants did not score significantly higher on the test of notions about teaching science than the rest of the group who worked with the resource.

Discussion

The results of this study point out several possible avenues for investigation involving the Science Helper search interface and database of inquiry-based science activities, as well as research involving the more general nature of distributed intelligence. Three areas of consideration are discussed in this section, followed by suggestions for research.

The results of this study indicate the need for further consideration of and research in the following three areas: (a) Science Helper and training in science processes; (b) training novice versus experienced teachers; and (c) issues of resistance to change. The next sections briefly outlines the research background, along with evidence from this study, that supports further consideration of these areas.

Science Helper and Training in Science Processes

The main question addressed by this study originated in anecdotal evidence that teachers working with Science Helper changed their ideas about teaching science in line with concepts reflected in reform documents, such as the National Science Education Standards (NRC, 1996). After the early days of training in the use of Science Helper, subsequent distribution of the resource has involved little or no training. The focus of the study was on effects that might arise from using the search interface and its associated criteria, specifically the science content and process themes, with limited training. Participants received basic instruction in using the search interface to find appropriate activities in the database of resources. Brief instruction was given on what "appropriate" lessons meant in respect to the large number of resources available in the database. This instruction consisted of explaining the difference between using a more familiar and typical keyword search, as opposed to using science content and process themes.

Participants were told to look at the Sunshine State Standards for Science (Florida Curriculum Framework for Science, 1996) to find terms similar to those in the search criteria lists. In other words, they might do a search for appropriate science lessons by using science content standards as a source of appropriate science content and, by identifying similar vocabulary, find appropriate lessons in the Science Helper database. The instruction in using the state content standards was brief and the meanings of search criteria terms were not covered, other than suggesting that participants look at examples of activities associated with those terms.

In addition, the current study did not provide the opportunity for participants to study the activities they were finding in their searches of the database; however, the experience provided the opportunity for them to see that searches produced lessons related by their shared search criteria. Having found no significant improvements in preservice teachers' notions about science teaching, further investigation might involve additional training in understanding science process skills. Such training might include practice using some of the many activities in the Science Helper database that emphasize those skills.

Training Novice Versus Experienced Teachers

As would be expected in training situations, inservice teachers bring with them greater knowledge of science teaching and, perhaps more important, greater exposure to expectations for teaching science, such as state and the national science content standards. Having taught science in the classroom, experienced teachers are more familiar with the processes of science, if only from having seen the terms in science curriculum materials.

In the early days of demonstrating and training educators to use Science Helper, E. D. Britton (personal communication, April 27, 1998) noticed that knowledge of the science processes in particular depended on length of experience in teaching, as might be expected. Experienced teachers, according to Britton, were more apt to notice how science processes were used in the activities in Science Helper's database. They were more likely to at least have had heard of these processes, even if they were unfamiliar with some of their meanings and uses in science. While many of the experienced teachers were not familiar with all the science processes used in the Science Helper search criteria, Britton found that trainees learned much about teaching the processes from reading the activities in the database.

Searches by those experienced teachers using the process criteria often elicited “a-hah” responses, Britton said, indicating that they were learning about the processes and how to teach them as they examined the inquiry-based activities. Even the listing of the process themes in the search criteria was educative for some of the experienced teachers who were less familiar with science processes, according to Britton. This researcher did not notice such reactions in the preservice teachers in the study, nor did they make related comments in their narratives.

Further research might be done comparing the experiences of novice teachers, such as the preservice teachers in this study, and the experiences of experienced teachers in extended training situations, as suggested in the previous section.

Issues of Resistance to Change

Resistance to conceptual change stands as a major concern in any study of change. Efforts to achieve conceptual change are limited by the persistence of previously held concepts. Lynch’s (1997) study of novice teachers’ encounter with science education reform materials supported evidence that reform efforts require both time and effective professional development. She cited research that teachers’ core beliefs must be aligned with curricular approaches, which requires time and appropriate activities to restructure "tenaciously held educational beliefs" (p. 5).

Other research on conceptual change shows the difficulty in promoting such change (e.g., Posner, Strike, Hewson, & Gertzog, 1982; Stofflett, 1994; Stofflett & Stoddart, 1994). Length and type of training can be expected to contribute to conceptual change but the research shows these factors alone may not be as important as other conditions. According to Posner et al. (1982), the basic conditions that must be met for conceptual change to occur include the following:

1. There must be dissatisfaction with existing conceptions.
2. A new conception must be intelligible.
3. A new conception must appear initially plausible.
4. A new conception should suggest the possibility of a fruitful research program.

Analysis of the narratives in present study provides evidence of such resistance to change. For example, despite being told that the process and content search criteria provide the most appropriate activities from the Science Helper database, a few participants insisted in that familiar keyword searches, or just selecting criteria at random, satisfied their needs quite well (see the narrative analysis section below). In the words of one participant, "We used the keyword search because it fit our need perfectly. The advantages of a keyword search is it is quick and effective." Another one explained, "As far as how I chose my criteria, I decided to use trial and error until I got to three articles. It may not have been the best method, but it worked for me."

Such anecdotal evidence from this study supports longer, more involved training sessions during which participants would have greater opportunity to learn how search criteria other than keywords provide more appropriate activities for inquiry-based science learning. The narrative comments indicate a desire to stick with familiar approaches or to take the easier route of selecting criteria at random. Additional familiarization with the search interface should provide opportunity for seeing the advantages of selecting appropriate search criteria.

Narrative Analysis Concerns and Observations

An important consideration when looking at counts or percentages for narrative pattern types is that, for the most part, these comments were not directly elicited. For example, it should not be implied that participants whose narratives did not include comments indicating appropriate use of search criteria when working with Science Helper did not understand such use; however, comments indicating appropriate usage provide insight into how participants developed such understandings.

This is an example of the use of the search interface to find appropriate activities for a participant's chosen topic:

> These activities go together because they all have the same criteria and can be elaborated on in this way. If you are focusing on recording and observing, then you

> have three perfect lessons to use. If you decide to work on patterns in nature, then again you have some wonderful lessons to teach.

An example of the advantages of this type of search over keywords for finding appropriate teaching resources in the database can be seen in this comment: "If you used this tool appropriately, then you would have the best lesson for what you wanted to teach. However, if you used a word search, you may not have the best lesson."

In contrast to these examples indicating appropriate usage of the search criteria, the following participant's comments represent an undesirable approach:

> We used almost every search criteria. I'll explain why we used them all instead of answering individually. We wanted to use as many criteria as we could and be as specific as possible with the lessons and activities. We felt the more criteria we used, the more it would narrow the responses to what we are looking for.

A higher percentage of participants made positive comments about Science Helper than negative comments but, again, this evidence should not necessarily be construed as indicating greater acceptance of the resource. Although participants were not held accountable for the quality or quantity of their narrative comments, the greater number of positive comments may represent a natural inclination to say something positive. Participants may have seen Science Helper as just another resource providing more options or opportunities for prospective teachers.

Having said that, a closer look at the positive comments can provide insight into how the participants found Science

Helper and the study experience to be useful. The following is an example of such comments:

> I think that using Science Helper was a great learning experience for me. I know that with my internship coming up in the fall that [I] will definitely want to use this program. Science is the subject I am the least confident in and after using this program for just a few days I feel more confident. I love the way you can choose a subject, content theme, and know exactly what processes to focus on your lessons. I enjoyed my experience with Science Helper! Thank you! I felt like I could teach this unit on Habitats tomorrow if given the opportunity!

Even though the study period was short and the results less than could be desired for appropriate use of Science Helper, four participants indicated they need not have spent so much time learning to use the resource. This result suggests that future training sessions place greater emphasis on the inquiry approach to learning perhaps by focusing on activities in the database that characterize the science process skills. That preservice teachers may not give much weight to process skills when choosing curricular material can be seen in the following comment: "I felt Science Helper could be beneficial if a teacher was defining a science lesson based on processes; however, in my experience, most teachers choose activities according to subject matter rather than process skills."

In addition to the narrative comments already discussed it also should be pointed out that, as can be seen in the summary of identified comment patterns, participants made a large number of comments on a wide range of notions about teaching science. These comments were not further analyzed for this study because they did not appear to have as strong a bearing on the results of working with Science Helper; however, research on the persistence of preservice teachers core beliefs and how those beliefs affect their decisions (Lynch, 1997) can be seen in these comments. This aspect of the participant comments also holds potential for further research.

Implications

In preservice teachers' most recent experiences with science--their undergraduate science courses--science is usually communicated "as a body of facts and rules to be memorized. . . . [E]ven the science laboratories in most colleges fail to teach science as inquiry" (NRC, 1996, p. 56). These are the same teachers who "will be representatives of the scientific community in their classrooms" (NRC, p. 61).

The implication is that, even though use of Science Helper by less experienced teachers or use without concomitant training may not promote more appropriate teaching of science, the addition of training and use of this resource may do so. Research to support this assertion remains to be done. However, support for doing such research and the need for training teachers in the culture of science can be found in recent studies. Roth, McGinn, and Bowen (1998, p. 42), for example, found that secondary preservice teachers with at least an undergraduate degree in science "did not engage to a higher degree in scientific representation practices"[1] than eighth-grade students "who had conducted investigations of their choice and design." In other words, the secondary preservice teachers, who would be expected to have far greater qualifications for teaching science than the elementary teachers considered in the current study, did not engage in practices used by professional scientists.

Roth, McGinn, and Bowen (1998) question whether such teachers would be able to provide an appropriate science education, as advocated in the mathematics and science standards. They suggest that appropriate practices develop within communities where such practices are common. In educational settings, such practices can be allowed to develop in "authentic learning environments where students engage in scientific and mathematical practices espoused by various standards" (p. 45). While these researchers advocate experiences in actual research, in both university- and industry-based laboratories, Choi & Hannafin (1995) advocate engagement in cognitive activities similar to those of the experts, representing authentic tasks in authentic contexts. These authentic activities should represent the ordinary practices of a culture (Brown, Collins, & Duguid, 1989).

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[1] The intent of the researchers was to determine if beginning teachers were prepared to teach inquiry, including data transformation and analysis. Their approach was to investigate the extent preservice teachers used inscriptions to analyze problems in ecology.

Soon after the development of Science Helper, state science supervisors acknowledged its potential for helping teachers learn the science processes (E. D. Britton, personal communication, April 27, 1998). The science processes represented in activities in the Science Helper database provide opportunities for both teachers and their students to engage in activities similar to the community of scientists. However, opportunities for teachers to engage in such activities during their preservice education remain limited. This issue of how to provide opportunities for practice must be addressed before further improvements can be expected in preservice science teacher education.

Directions for Future Research

The above discussion offers suggestions for further investigation based on the results of this study. Those suggestions include investigating the use of Science Helper within a broader training experience that includes studying the science process skills; determining the different needs of novice teachers and experienced teachers to provide appropriate training in the use of Science Helper; and applying research on resistance to change to provide better training situations for learning more appropriate approaches to teaching science.

Aspects of these suggestions can be combined in a research program that includes the use of Science Helper for learning the science process skills within an inquiry-based approach to learning about science. The research design could consist of a comparison study that engages separate groups of experienced and novice teachers learning about science process skills through using the Science Helper search interface to find appropriate activities, and then studying those resources closely. Practice using the activities with students might be the most effective approach.

For comparison between approaches to learning science processes, other groups of experienced and novice teachers would study the science processes using a different learning approach, such as studying the National Science Education Standards (NRC, 1996. After similar immersion times, the groups would be tested for improvements in their notions about teaching science in the same manner as this study. In addition, differences between novice and experienced teachers learning of the processes could be determined.

Training teachers to find science activities in the Science Helper database and practice using them may engage teachers to the extent that the resource serves as a conceptual tools whose use may "entail both changing the user's view of the world and adopting the belief system of the culture in which they are used" (Brown, Collins, & Duguid, 1989, p. 33).

A comparison study should not be the only approach to learning more about the use of Science Helper to promote inquiry-based learning. Teachers who use the resource to find appropriate inquiry-based activities and then use those activities in their classrooms could become the subjects of a longitudinal study of conceptual change. Analyzing teachers' notions about learning science over a longer period and with greater involvement with the resource may provide evidence of the conceptual change that was not observed in the current study.

In this proposed longitudinal study, besides spending more time with inquiry-based lessons, teachers would learn more science content while using the selected activities in their classrooms. Greater content knowledge should be a factor in teachers' understanding of appropriate approaches to teaching science and, thus, should be examined in a study of this type.

The researcher hopes that future research will determine whether Science Helper can serve as a tool for authentic learning. This goal requires research that looks at the social component along with the material component, studying interactions among the people and the resources in a distributed environment. According to Lynch's (1997) analysis of research on exposure to goals of science education reform:

> . . . long-term, intellectually engaging activities are needed to allow teachers to discuss their beliefs and reflect on and confront inconsistencies between beliefs and reform goals. (p. 7)

Within the sphere of conceptual change theory, Feiman-Nemser & Remillard (1996) recommend providing teachers with opportunities to consider why new practices and their associated values and beliefs are better. The teachers need to see examples of such practices, and they should experience such practices firsthand as learners. The researchers suggest the advantage of cognitive apprenticeships, which provide authentic activity, social interactions, and other features that support the use of an educational community of practice.

An appropriate training situation for learning about inquiry through the use of Science Helper should consider the importance of establishing such communities of practice within which teachers can reach shared understandings of the meanings of what they are doing (Pea, 1992). Through becoming familiar with scientific terms, such as the science processes, Pea said participants can begin to engage in scientific conversations through which meaning is communicated and developed. However, it must be recognized that such conversations take place within the unique culture of the education community, as opposed to within the scientific community. It is within this culture that "ideas are exchanged and modified and belief systems developed and appropriated through conversation and narratives, so these must be promoted, not inhibited" (Brown, Collins, & Duguid, 1989, p. 40).

Conclusion

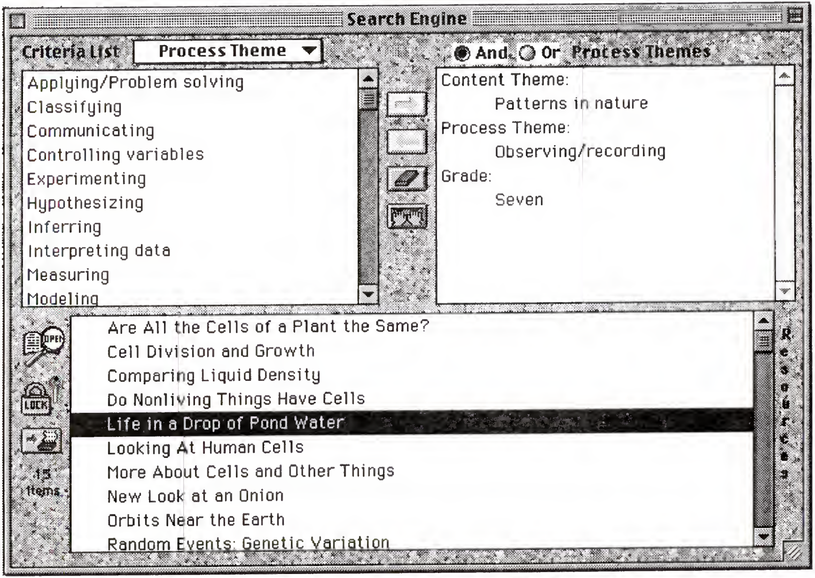
The results of this study provide insight into some of the difficulties in improving teachers notions about teaching science. The results also provide a basis for further investigations of the Science Helper CD as a resource for teacher education involving science processes and an inquiry-based approaches to learning about science.

Although the social component, specifically, the social distribution of intelligence (Pea, 1993), was not included in this study, it may prove to be the most important component for promoting change in notions about teaching. Appropriate and effective efforts to align teacher beliefs and concepts of science teaching with reform materials such as the Standards will most likely depend on social interactions involving the use of situationally provided tools for engaging in authentic activities within communities of practice (Wilson, 1993).

According to Wilson, "it is the interaction with the setting itself in relation to its social and tool-dependent nature that determines the learning" (p. 73). That learning "is a recursive process in which adults act in and interact with context." The researcher hopes to engage in further research, as discussed in the preceding sections, that investigates the interactions among the people and resources in contextually rich distributed environments.

APPENDIX A
SCIENCE HELPER SEARCH EXAMPLE

Figure A-1 shows an example of a Science Helper search window. Users select search criteria from the Criteria List, a pull-down menu in the upper left of the search window. The Criteria List contains science content and process themes, subjects, keywords, project titles, resource types, grade levels, book titles, and link types. In the example, the upper left box shows the science process themes. The process theme, "observing/ recording," has been selected, along with the content theme, "patterns in nature," and grade seven, in the example search. The upper right box shows these selected criteria. As a result of this search of the database of science resources, the titles of 15 items appear in the Resources box on the bottom. Before a search, the Resources box shows all of the nearly 1,000 titles available in the database, most of which are science activities. As soon as search criteria have been selected, the box shows only the titles with those criteria, as in the example. Having done a search in this manner, the user can look at materials in the database simply by highlighting a resource title, as shown, and clicking the "open" icon to the left of the Resources box. An abstract appears first, providing a brief summary of that resource.



Applying/Problem solving
Classifying
Communicating
Controlling variables
Experimenting
Hypothesizing
Inferring
Interpreting data
Measuring
Modeling

Content Theme:
Patterns in nature
Process Theme:
Observing/recording
Grade:
Seven

Are All the Cells of a Plant the Same?
Cell Division and Growth
Comparing Liquid Density
Do Nonliving Things Have Cells
Life in a Drop of Pond Water
Looking At Human Cells
More About Cells and Other Things
New Look at an Onion
Orbits Near the Earth
Random Events: Genetic Variation

Figure A-1. Example of a Science Helper Search Window

APPENDIX B
EXAMPLES FROM SCIENCE FOR ALL STUDENTS

The following material was used as an overhead transparency to present study participants with examples of wording used in Science for All Students (Florida Department of Education, n. d.) which could be used to guide their selections of Science Helper search criteria, especially content themes and processes of science, used in the search interface.

From Science for All Students, examples of what all elementary students should be able to do:

- Use scientific equipment to classify or order a set of objects using length, weight, or volume. Explain the classification scheme used. (Strand 1. The Nature of Matter)
- Design an experiment to show that some materials conduct heat better than others. (Strand 2. Energy)
- Design an experiment to identify the effects of light energy on plant growth. (Strand 2. Energy)
- Measure the gravitational force on their bodies by standing on a scale. (Strand 3. Force and Motion)
- Explore water samples gathered from a variety of sources such as lakes, canals, wells, streams, and bays. Draw inferences from observations. (Strand 4. Processes That Shape the Earth)
- Demonstrate and relate day and night to the rotation of the Earth on its axis and the concept of seasons to Earth's tilted axis. (Strand 5. Earth and Space)

- Using available materials, make a model of the human body that shows major organ systems. Use the model to make a class presentation on how these systems work. (Strand 6. Processes of Life)

- Using populations of brine shrimp, radish seeds, or other rapidly-reproducing organisms, make observations, collect data, and make inferences about the results of uncontrolled population growth in a population with limited resources in its environment. (Strand 7. How Living Things Interact with Their Environment)

- Develop alternative interpretations based upon the experimental evidence collected. For instance, when asked the question, "Can meal worms see?", work in teams, do direct observations, compare findings with those of other teams, and where disagreements exist, devise investigations that resolve the issue or propose alternative hypotheses. (Strand 8. Nature of Science)

APPENDIX C
MINI-UNIT ASSIGNMENT

After brief practice using the Science Helper search interface, study participants emailed examples of search criteria and titles they found. In reply, they were emailed the following instructions for their assignment which involved using Science Helper to find lessons for a mini-unit:

Science Helper/Sunshine State Science Standards Assignment

You should try to finish the assignment during class on Thursday, April 17; however, I will accept work up to 4 pm Friday, April 18.

Nature of the assignment:

Using the Science Helper search system, identify three or four appropriate activities that could be used in a science mini-unit. The activities all should result from a single search using criteria you select. To begin the assignment, decide on a topic, theme, or science objective. You may wish to use a Sunshine State standard as your topic. Then decide upon the appropriate criteria for teaching your topic. The criteria used should reflect the knowledge and skills required for students to understand the science topic.

You can determine the appropriateness of the search criteria by how well they match up with the Sunshine State standards. The most important criteria to use for the search are the content themes and process themes. These criteria will give you lessons that provide students with both the knowledge and skills for understanding the science concepts covered by your topic.

After you complete your search for appropriate activities, identify the additional standards that each activity addresses. Submit the following information in the database provided:

* Summaries of activities, including lesson titles, materials, and procedures
* Selection criteria (grade level, content themes, process themes, and others) used for the search
* Standards addressed by *each* of the activities

To complete the assignment, simply start a new record in the database and provide the requested information. A discussion of how to fill out the records in the database will be provided in class. In addition, after you have completed the database for your activities, write a brief narrative of your experiences doing the assignment. Your narrative should include the following:

* a brief description of how you chose the topic for your mini-unit
* a discussion of why you chose to use each of the search criteria
* a brief discussion of how you might go about using the activities together as a unit
* your comments about the advantages of identifying appropriate activities in this way
* any other comments or concerns you have about doing this assignment

Reply to this email with any questions you have about the assignment.

APPENDIX D
INSTRUMENT ITEMS

The following multiple-choice items represent all items used in the study instrument. Bold letters represent the most appropriate responses. A total of 32 items were used, divided randomly into two forms of 16 items. Forms were randomly distributed in both treatment and control groups.

An elementary school science program that is contemporary in approach will probably use
a. guided discovery.
b. inductive thinking.
c. deductive thinking.
d. all of the above.

A science program for children can be most effective by
a. building a science program around the science that evolves from the children's school activities.
b. following the science sequence of the assigned textbook.
c. planning a carefully sequenced science program combining understanding and skill, that meets the concept development of the children.
d. using an experimental science curriculum as developed by a national group or a university.

Evaluating children's science development can best be accomplished by
a. observing behavioral changes in children.
b. administering a test on the science taught.
c. administering the test given at the end of each chapter in the child's science textbook.
d. asking each child what he or she knows.

A good elementary science teacher should have knowledge of science concepts and knowledge of appropriate science teaching strategies. What relationship should exist between these two types of knowledge?
a. Learning science concepts will lead to an understanding of science teaching strategies.

b. A program of science courses, as well as study of science teaching strategies, is necessary.
c. Study of science teaching strategies provides all of the necessary knowledge of science concepts.
d. Knowledge of science concepts is the main requirement for becoming a good teacher of elementary science.

Which of the following statements represents the most effective teaching skill for teaching science to children?
a. Demonstrating a science concept for the children, then giving them the directions for doing a similar activity.
b. Beginning with a situation for motivation and then letting the children design experiments to explore a science concept.
c. Developing structured activities that help children learn a science concept.
d. Demonstrating for children how the concept to be learned can be applied to life situations.

Which of these statements least describes a contemporary elementary science program?
a. Science is learned mainly by following the steps of a structured experiment correctly.
b. Science is taught as a set of understandable ideas.
c. Scientific concepts should be discovered by the learner.
d. Learning progresses from the concrete level of the real world to abstract science concepts.

Which of the following approaches is not associated with a contemporary science program?
a. Life science concepts are taught at every grade level.
b. Physical science concepts are introduced beginning in the primary grades.
c. Basic facts need not be memorized if children understand basic structure.
d. More emphasis is being place upon understanding.

An elementary science textbook should be used
a. as the sequence to follow.
b. as a guide but not followed.
c. for solving problems only.
d. none of the above.

A good elementary school science program places more emphasis on
a. focusing on student acquisition of information.
b. selecting and adapting the curriculum.
c. continuously assessing student understanding.
d. both b. and c.

Discourse in the science classroom
a. should predominantly be by the teacher explaining science to the students.
b. should predominantly be by the students explaining science discoveries to their peers and the teacher.

c. should be by the students explaining how the assigned examples were solved.
d. by the students should be discouraged as it wastes too much class time.

Instructional objectives for science lessons should be
a. written in terms of the teacher's procedures.
b. a broad statement indicating general outcomes.
c. written in terms of observable behaviors displayed by the students.
d. a statement of the content to be explained to the students.

Developing science concepts within students
a. is accomplished most effectively by teachers explaining science to students.
b. is best accomplished by teachers demonstrating science concepts by manipulative materials.
c. is most effective by students using materials to demonstrate a new concept.
d. is most effective by having students learn the standard laws and definitions.

Science lessons planned by teachers should be based upon
a. the textbook adopted by the school system.
b. the standardized tests to be administered at the end of the school year.
c. the students' past experiences and science understandings.
d. the tests provided in the teacher's textbook manual.

It is best to end a science lesson by
a. the teacher assigning a series of examples to be solved from the textbook.
b. helping students to orally state what was learned in today's science lesson.
c. having students write a paragraph describing what was learned in today's science lesson.
d. both b. and c.

An elementary school science textbook should be used
a. as a reference and guide but not necessarily followed.
b. as the science sequence to follow.
c. for problem-solving exercises only.
d. as the main science explanations for the students.

Teachers can best evaluate the science learning of the students by
a. administering the textbook tests.
b. observing the science behavior of the students.
c. administering a standardized test.
d. administering a teacher made test.

Successful science classrooms are classrooms in which
a. a variety of types of lessons are used.

b. material manipulated by the students and teachers demonstrate science concepts.
c. group activities and whole-class discussions are an integral part of the science program.
d. all of the above.

Using classroom manipulative material as part of the science instruction is
a. essential for promoting understanding and skill.
b. appropriate for small group instruction only.
c. appropriate for some but not all science concepts.
d. too time consuming for the benefits received.

Which of the following most accurately describes assessment?
a. Assessment is a process through which grades are determined.
b. Assessment is an information-gathering process.
c. Assessment is concerned with cognitive, not affective characteristics.
d. Assessment is most effective when it is objective.

Which of the following is not a benefit of using investigations or projects for student assessment?
a. Teachers most often gain a significant insight into how students go about problem solving.
b. Teachers often gain a significant insight into how students work together in teams.
c. students get an opportunity to see science as a process over time, rather than a collection of isolated skill.
d. Students always enjoy projects because they are more real-life and applied than traditional tasks in science.

Which of the following assessment techniques would be most appropriate for use in the kindergarten or first grade classroom?
a. Science journals
b. Interviews
c. Open-ended questions
d. Paper-and-pencil skill tests

Which of the following is not a basic assumption of contemporary science teaching?
a. What science students learn is greatly influenced by how they are taught.
b. Teachers' actions are deeply influenced by their perceptions of science as an enterprise and as a subject to be taught and learned.
c. Student understanding is actively constructed through attending to teacher presentations and working independently on textbook exercises.
d. Teachers' actions are deeply influenced by their understanding of and relationships with students.

Teachers planning an inquiry-based science program should

a. select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities, and experience of students.
b. prepare presentations and study of scientific knowledge through lectures, textbook exercises, and teacher demonstrations.
c. prepare end of unit and end of chapter tests of student ability to remember factual information.
d. both b and c.

Teachers guide and facilitate the learning of science through inquiry by
a. treating all students alike and responding to the class as a whole.
b. rigidly following a well-planned curriculum throughout the school year.
c. promoting understanding by asking for student recitation of acquired science knowledge.
d. orchestrating discourse among students about scientific ideas.

Teachers engage in ongoing assessment of their teaching and student learning by
a. guiding their students in self-assessment.
b. using multiple methods and systematically gathering data about student understanding and ability.
c. using student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching practice.
d. all of the above.

Teachers promote appropriate attitudes about learning science by
a. expecting all students to express similar ideas, to demonstrate similar skills, and to have had similar experiences.
b. making the important decisions about content and context of student work without requiring students to take responsibility for the learning of other members of the class.
c. structuring and facilitating ongoing formal and informal discussion based on a shared understanding of the rules of scientific discourse.
d. modeling the skills, attitudes, and values of scientific inquiry by nurturing and supporting competition among students.

Learning experiences for preservice teachers of science should not
a. connect and integrate all pertinent aspects of science and science education.
b. occur in a variety of places where effective science teaching can be illustrated and modeled.

c. address teachers' needs as learners and build on their current knowledge of science content, teaching, and learning.
d. take place in education courses that emphasize transmission of teaching knowledge and skills by lectures.

Professional development opportunities for teachers of science should provide opportunities
a. for developing reliance on external expertise for science instruction.
b. to know and have access to existing research and experiential knowledge.
c. for individual and collegial examination and reflection on classroom and institutional practice.
d. both b and c.

The science content in a contemporary science program places more emphasis on
a. knowing scientific facts and information.
b. activities that investigate and analyze science questions.
c. activities that demonstrate and verify the science content.
d. individual process skills such as observation and inference.

The contemporary teacher of science places less emphasis on
a. understanding and responding to individual students' interests, strengths, experiences, and needs.
b. providing opportunities for scientific discussion and debate among students.
c. maintaining the teacher's position of responsibility and authority.
d. sharing responsibility for learning with students.

A contemporary program for learning how to teach science places less emphasis on
a. the teacher as a consumer of knowledge about teaching.
b. learning science through investigation and inquiry.
c. the teacher as intellectual, reflective practitioner.
d. integration of science and teaching knowledge.

A contemporary approach to science understanding places less emphasis on assessing
a. scientific knowledge.
b. scientific understanding and reasoning.
c. achievement and opportunity to learn.
d. rich, well-structured knowledge.

APPENDIX E
PATTERN CATEGORIES MARKUP EXAMPLES

Table E-1 shows pattern categories identified in participant narrative comments. The table also shows codes used to markup narratives. Examples of coded narratives showing category types follow the table.

Table E-1

General Pattern Categories and Codes

Categories	Codes
General notions about science and science teaching	GN
References to search criteria content and process themes	SC
Positive comments about Science Helper or study	PS
Negative comments about Science Helper or study	NS
Comments indicating appropriate usage of Science Helper	AU
Comments indicating undesirable usage of resource	UU
Comments on how activities help students learn	SL

GN: "Children in this classroom work on this skill extensively, but can always use more practice."

SC: "The first search criteria I chose was the content theme interaction/change in systems. . . . Next, I chose the process theme observing and recording."

PS: "It is very easy to use and you get quick and easy results. . . . I believe that Science Helper could be a great help to many teachers."

NS: "This program does not work well if you are only looking for a particular subject for example Rain Forest."

AU: “There are many advantages of identifying appropriate activities in this way. First, it is very teacher-friendly in that all you have to do is type in what you wish to teach (i.e. what type of process theme you want to focus on, content theme, etc.).”

UU: “As far as how I chose my criteria, I decided to use trial and error until I got to three articles. It may not have been the best method, but it worked for me.”

SL: “The unit would start with the introduction of the Operational Definitions of Plant Parts lesson. This will get the students to look closely at the parts of different plants and the working of plants.”

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BIOGRAPHICAL SKETCH

William Dwyer grew up in the Midwest. He went to the University of California at Berkeley where he obtained his undergraduate degree in astronomy. He then spent four years in Tokyo, Japan, where he taught English conversation classes. He returned to the San Francisco Bay Area and taught high school physics and chemistry for five years. He then obtained a Master of Science degree in journalism at the University of Illinois, Urbana-Champaign, followed by a Master of Education degree.

While his wife studied to be a nurse practitioner at the University of Florida, he pursued his doctorate and worked on science curriculum projects for Dr. Mary Budd Rowe, including the Science Helper video series, the Culture & Technology CD-ROM, and the Enhanced Science Helper CD. He also worked on outside projects with Dr. Richard Ledbetter and The Learning Team, including the High School Biology project for Apple Computer, Inc., the National Science Education Standards Awareness Kits, and the Investigating Lake Iluka, Classroom Edition. He accepted a position as Assistant Professor of Science Education at the University of Alabama, Tuscaloosa.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Education.

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